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(54) Annular seals

(57) An annular sealing arrangement is provided for joining an annular combustor to the turbine inlet nozzle 14 of a gas turbine engine, the sealing arrangement accommodating axial and radial differential thermal expansion and contraction and dimensional stack-up tolerances of the turbine combustor and nozzle, and minimizing fluid leakage across and vibration of the sealing and joining structure therebetween. The sealing arrangement comprises a transversely split circumferentially elastic ring 20 having axial 25 and radial 23 sections in slidable sealing engagement with axial 21 and radial 22 flanges, respectively, extending from the turbine combustor and nozzle. Each axial and radial section of the ring cooperates with the respective flange in a tongue and groove arrangement for providing a tight sliding fit and frictional damping.

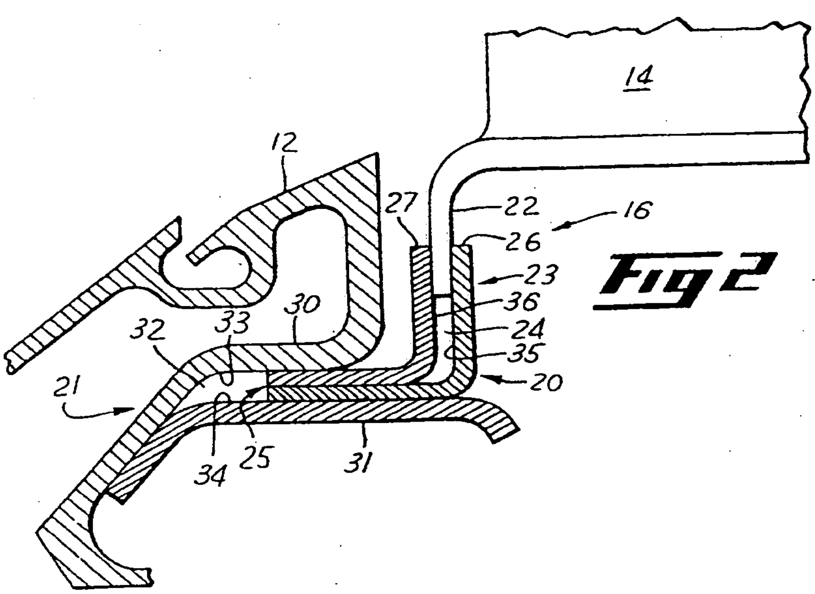

Fig 2

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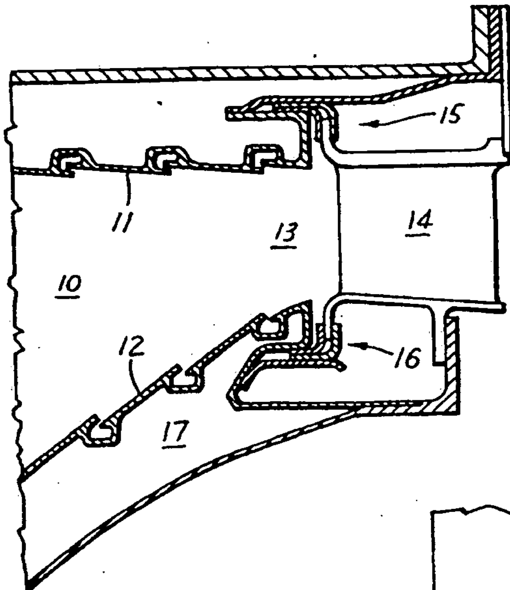

Fig 1

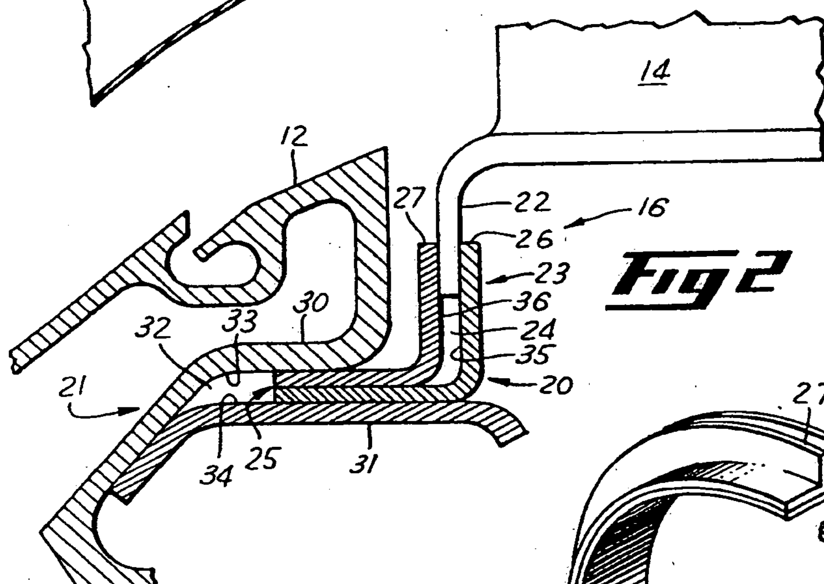

Fig 2

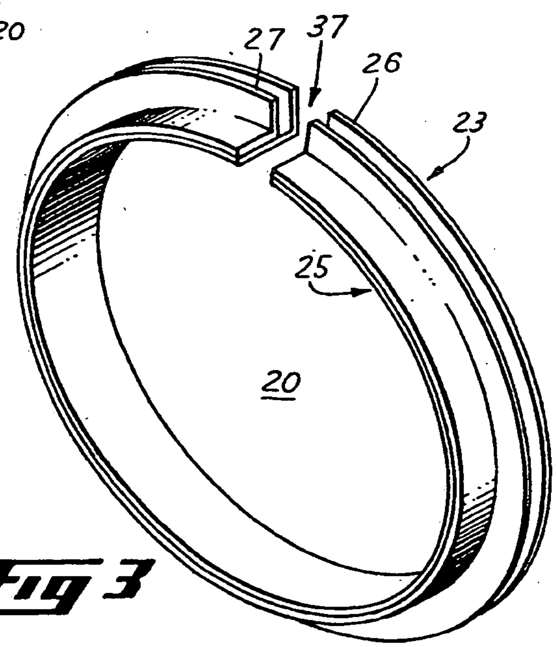

Fig 3

SPECIFICATION

Seal structure

This invention relates to annular seal structures in gas turbine engines and more specifically to an annular seal structure for joining an annular combustor to the turbine nozzle of a gas turbine engine.

In modern gas turbine engines, major components of the engine are designed to be assembled and disassembled in modules. During engine operation, these modules thermally expand and contract both axially and radially due to temperature differences in different sections of the engine. The means of attachment between these modules must be capable of dimensionally absorbing this expansion and contraction. In addition, at some points of attachment, these modules define boundaries between co-annular fluid flowpaths that are pressurized to different levels. To prevent leakage between the fluid flowpaths, the means of attachment must also maintain an effective sealing relationship therebetween such as, for example, between the relatively low pressure gas flowpath products of the combustor and the relatively high pressure cooling air flowing through a surrounding cooling plenum.

The large pressure differences which exist between the two fluid flowpaths often cause portions of the means of attachment to become self-excited by any fluid leakage across the sealing structure thereof. This self-excitation is referred to by those skilled in the art as aeroelastic instability. A condition of aeroelastic instability often leads to excessive and uncontrolled vibration which can lead to wear and rapid fatigue failure or cracking of the combustor, turbine members, or sections of the seal structure itself. Failure in the sealing structure can result in small pieces of the seal being blown into the gas flowpath of the engine causing damage to downstream parts. Therefore, means for preventing excessive vibration in the sealing structure are also necessary to maintain successful engine operation.

A particular type of seal structure known to those skilled in thart that accomplishes these functions and that has been successfully employed as an attachment means between modules in gas turbine engines is a "floating fishmouth seal", one embodiment of which is disclosed in U.S. Patent 4,251,986 — Thompson et al., incorporated herein by reference and assigned to the same assignee as the present invention. The floating fishmouth seal disclosed therein comprises two sections, a male section and a female section. The male section comprises a circumferentially continuous or non-split annular member having an axial portion that partially extends into an annular inlet in the female section which female section extends from a combustor. The female section comprises two axially extending annular arms that are joined together at one end and are disposed in parallel spaced alignment at the other end for thereby forming the annular inlet. The floating fishmouth seal will accommodate expansion and contraction in both the radial and axial directions, because the male section can move both radially and axially within the annular inlet in the female section and still maintain a sealing contact.

More specifically, the male section extends partially into the annular inlet such that an axial clearance gap exists within the inlet for accommodating differential axial movements, and is also in contact with one of the two annular arms with a radial clearance gap existing between the male section and the other of the two annular arms for accommodating radial differential movements. The extent of the radial clearance gap is predetermined by taking into account the maximum expected manufacturing radial stack-up tolerances and radial differential expansion and contraction to be accommodated by the seal structure such that the axial portion of the male section is only elastically deflected when pressing against either of the two annular arms for providing sealing and accommodating differential radial movements.

While the capability of the fishmouth seal to absorb dimensional variations is very desirable in gas turbine engine applications, the relative movement of the male and female sections of the fishmouth seal tends to allow vibration within the sealing structure. Any propensity to vibrate can be exaggerated under the extreme pressure and high rotational velocities incurred during gas turbine operation. These conditions can be particularly troublesome in flexible sealing structures as above-described in which there are wide temperature differences and in which relatively large manufacturing dimensional stack-up tolerances or variations are present. To minimize vibration, the sealing structure of Thompson et al. also comprises an additional stiffening structure for increasing torsional rigidity of the female section of the fishmouth seal structure and curved leaf springs that press a radially extending portion of the floating male section of the seal against a stationary lip within the engine for providing dry coulomb damping and sealing.

The use of a radial clearance gap as above-described for accommodating radial movement in the seal structure can result in fluid leakage therethrough during some stages of operation when the male section is in an intermediate position and thus not in contact with the two annular arms and can also lead to inducing vibrations, for example, vibrations of the combustor and the annular members of the fishmouth seal. The use of a minimum clearance gap to avoid leakage can lead in some circumstances to the male member being highly stressed and plastically deformed when accommodating unexpectedly large differential radial expansions and contractions or dimensional stack-up tolerances. Therefore, means for accommodating axial and radial differential thermal expansion and contraction and dimensional stack-up tolerances of the turbine

combustor and inlet nozzle, and for minimizing fluid leakage across and vibration of the sealing and joining structure therebetween, are necessary to maintain successful engine operation.

Accordingly, it is an object of the present invention to provide a new and improved annular seal structure for sealingly joining a pair of coaxial annular members that accommodates both axial and radial differential expansion and contraction, and stack-up tolerances.

Additionally, it is an object of the present invention to provide a new and improved annular seal structure that accommodates both axial and radial expansion and contraction between the combustor and the turbine nozzle of a gas turbine engine.

Another object of the present invention is to provide a new and improved annular seal structure that provides positive and controlled sealing and minimizes fluid leakage and induced vibration resulting therefrom.

Another object of the present invention is to provide a new and improved annular seal structure having tightly fitting components effective for both sealing and providing vibration damping.

According to the present invention, there is provided a sealing arrangement for joining a pair of coaxial annular members, such as an annular turbine combustor and a coaxial annular turbine nozzle of an axial flow gas turbine engine. The sealing arrangement comprises a transversely split circumferentially elastic annular sealing member having an axially extending annular section and an integral radially extending annular section, which axial and radial sections are in slidable sealing engagement with annular axial and radial flanges, respectively, extending from the turbine combustor and inlet nozzoe. In one embodiment of the invention, the axial section of the sealing member defines an axial tongue which is received in slidable sealing engagement with a complementary axial groove in the axial flange extending from the turbine combustor, and the radial section comprises a radial groove therein receiving in slidable sealing engagement an annular radial tongue defined by the radial flange extending from the inlet nozzle. The annular sealing member can advantageously be a composite structure comprising a pair of coaxial annular members each having axial and radial annular portions. The axial portions are rigidly interconnected in parallel alignment for defining the axial tongue of said annular sealing member. The radial portions are axially spaced in parallel alignment for defining therebetween the radial groove of the annular sealing member.

The invention, together with further objects and advantages thereof, is more particularly described in the following detailed description taken in conjunction with the accompanying drawing, in which

FIGURE 1 illustrates a cross-sectional view of annular inner and outer seal structures according to this invention in combination with the annular combustor and inlet nozzle of a gas turbine engine;

FIGURE 2 illustrates a detailed fragmentary cross-sectional view of the inner seal structure; and

FIGURE 3 illustrates a perspective view of the annular sealing member of this invention transversely split to provide an end gap therein.

Referring to FIGURE 1, an interior portion of an axial flow gas turbine aircraft engine is shown wherein one embodiment of a floating fishmouth seal arrangement according to this invention may be usefully employed. Shown is a portion of an aft end mounted annular combustor 10 comprising an annular outer combustor liner 11 coaxially spaced from and surrounding an annular inner combustor liner 12 for defining an annular flowpath therebetween in which hot combustion gases are generated and flow to an annular combustor outlet 13. The combustor outlet 13 directs the combustion gases from the annular flowpath of combustor 10 into a co-annular turbine nozzle 14 of a turbine section of the engine, which nozzle 14 comprises a plurality of circumferentially spaced inlet vanes.

The combustor section 10 must be connected to the turbine section with sealing structure that can absorb changes in position of the combustor and turbine sections during operation and simultaneously prevent fluid leakage across the seal. An annular radially outer sealing structure 15 and an annular radially inner sealing structure 16 are provided for this purpose and are effective for preventing high pressure cooling air from leaking into the relatively low pressure region between the combustor outlet 13 and the turbine nozzle 14. In the region surrounding inner seal 16, for example, cooling air that has been fully compressed by a compressor section flows through a cooling air duct 17 and continues aft in the engine to cool the hot turbine parts. Inner seal 16 must prevent leakage of cooling air from duct 17 into the flowpath of the products of combustion and must simultaneouly absorb any dimensional changes of the combustor section in relation to the turbine section during operation.

According to the present invention, a new and improved annular sealing structure is provided which comprises a transversely split circumferentially elastic ring having axial and radial sections in slidable sealing engagement with axial and radial flanges, respectively, extending from the turbine combustor and nozzle. Each axial and radial section of the ring cooperates with the respective flange in a tongue and groove arrangement for providing a tight sliding fit and frictional damping.

Shown in more detail in FIGURE 2 is the inner sealing structure 16 according to the present invention which comprises a ring or annular sealing member 20 coaxially disposed between and in frictional sealing engagement with an annular axial flange 21 extending from combustor liner 12 and an annular radial flange or tongue 22 extending radially inwardly from nozzle 14. Annular flanges 21 and 22 are suitably secured to

combustor liner 12 and nozzle 14 by being, for example, either integral therewith or bolted thereto, respectively.

Sealing member 20 comprises an annular outwardly extending radial section 23 having an annular radial groove 24 therein, and an annular axial section or tongue 25 suitably joined perpendicular to radial section 23 and preferably integral therewith. More specifically, sealing member 20 is a composite structure having a pair of coaxial annular elements 26 and 27 each including integral annular axial and radial portions of approximately equal lengths. The axial portions of sealing member 20 are suitably rigidly joined or interconnected, for example, by brazing or welding in parallel alignment for defining the axial tongue 25. The radial portions are axially spaced in parallel alignment and define therebetween the radial groove 24 in radial section 23 for slidably receiving the radial tongue 22.

Axial flange 21 of combustor liner 12 comprises an annular upper arm 30 extending axially from and being integral with the combustor outlet end of the inner combustor liner 12, and an axially extending annular lower arm 31 rigidly joined to upper arm 30 at one end. Upper arm 30 and lower arm 31 extend axially in radially spaced parallel alignment for defining an annular axial groove 32 therebetween for receiving axial tongue 25 of the sealing member 20.

In order to form an improved sealing arrangement, axial tongue 25 of ring 20 is tightly slidably disposed in axial groove 32, the oppositely facing surfaces of axial tongue 25 being in frictional sealing engagement with both oppositely facing sidewall surfaces 33 and 34 of upper and lower arms 30 and 31, respectively. Axial grooves 32 is of sufficient depth and includes an axial clearance gap between the base thereof and the tip of axial tongue 25 to accommodate axial longitudinal movement of axial tongue 25 therein, thereby accommodating axial differential dimensional changes of the combustor 10 with respect to turbine nozzle 14.

Similarly, radial tongue 22, extending radially inwardly from the turbine nozzle 14, is tightly slidably disposed in radial groove 24. More specifically, the oppositely facing surfaces of radial tongue 22 are in frictional sealing engagement with both oppositely facing sidewall surfaces 35 and 36 of the radial portions of the annular elements 26 and 27, respectively, which define radial groove 24. Radial groove 24 is of sufficient depth and includes a radial clearance gap between the base thereof and the tip of radial tongue 22 to accommodate radial longitudinal movement of tongue 22 therein, thereby accommodating radial differential dimensional changes of combustor 10 with respect to turbine nozzle 14.

In a floating fishmouth seal, the ring 20 is not fixed to any structure and it is, therefore, free to float radially and axially within a predetermined strictly confined region. During engine operation, the ring 20 moves to accommodate relative changes in axial and radial dimension and position of the combustor 10 and nozzle 14 forming the boundaries of the sealing relationship. As shown in FIGURE 2, the axial tongue 25 of ring 20 engages the two oppositely facing sidewalls 33 and 34 of the axial flange 21, thereby forming one end of the sealing arrangement. An opposite end of the sealing arrangement is formed by the radial tongue 22 engaging the two oppositely facing sidewalls 35 and 36 of annular elements 26 and 27 of ring 20.

Although a sealing relationship must necessarily be formed at the radial and axial portions of the ring 20, the ring 20 must also accommodate both axial and radial dimensional variations within the gas turbine engine as above-described. However, due to the fact that ring 20 and combustor liner 12 do not thermally expand and contract simultaneously, means for accommodating any relative differential radial movements therebetween is necessary. In the prior art arrangement of Thompson et al., for example, a radial clearance gap is provided within the annular inlet (axial groove 32) for allowing the male section (axial tongue 25) to move radially laterally therein and press against the sidewalls thereof. The use of this arrangement can in some stages of operation result in fluid leakage around axial tongue 25 and subject, especially the axial tongue 25 of ring 20, to relatively high bending stress, as above-described.

In the present invention, and by predeterminedly spacing the elements defining the grooves relative to the dimensions of the elements constituting the tongues, the radial clearance gap between axial tongue 25 and the sidewall surfaces 33 and 34 of axial flange 21 is substantially zero in magnitude for providing a consistently effective seal having substantially no fluid leakage therethrough. To accommodate the relative differential radial expansion and contraction and radial manufacturing dimensional stack-up tolerances of ring 20 and inner combustor liner 12, ring 20 comprises a circumferentially elastic member being transversely split at one cross-section thereof and having a transverse end gap 37, as shown in FIGURE 3. End gap 37 is approximately 40—50 mils long and is shown greatly exaggerated in FIGURE 3 for illustrative purpose. Ring 20, therefore, is split in one transverse cross-section and can be functionally comparable to a piston ring as used in piston seal arrangements. Although providing the end gap 37 in ring 20 creates fluid leakage through the inner sealing structure 16, such leakage is relatively minimal and tolerable, especially when considering the many advantages which result from the use of a sealing structure having a transversely split sealing member.

The relative differential radial thermal expansion and contraction of ring 20 and the combustor 10, particularly inner combustor liner 12, is accommodated by the elastic increase and decrease of the diameter of ring 20 and a corresponding increase and decrease of the transverse end gap 37 as ring 20 is urged to

follow the expansion and contraction of inner combustor liner 12. To allow the diameter of ring 20 to elastically increase and decrease as ring 20 follows the expansion and contraction of inner combustor liner 12, the radial tongue 22 of turbine nozzle 14 translates or slides radially relative to and within radial groove 24 of the radial section 23 of ring 20. This split ring arrangement is effective for minimizing the stresses in ring 20 and, more specifically, substantially eliminates that component of bending stress in axial tongue 25 due to radial differential movements of combustor inner liner 12 and ring 20. Ring 20 is, therefore, substantially stress free and in contrast to rings found in the prior art does not rely upon the bending of its axial section or material resilience in its transverse plane for continued sealing and accommodation of such radial differential movements.

The sealing arrangement of the present invention, therefore, which comprises a transversely split ring 20 and radial and axial tongue and groove sections provides positive, controlled sealing while accommodating relative differential radial expansion and contraction of inner combustor liner 12 and turbine nozzle 14. Additionally, relative differential axial expansion and contraction of inner combustor liner 12 and turbine nozzle 14 is accommodated by the translation or sliding of axial tongue 25 within axial groove 32 of annular flange 21 extending from inner combustor liner 12.

Furthermore, the tongue and groove sections of the sealing arrangement are effective for eliminating or minimizing leakage across inner seal 16 and, accordingly, leakage induced vibration of the inner seal 16 is also minimized or eliminated. Additionally, due to the fact that axial tongue 25 and radial tongue 22 frictionally engage axial groove 32 and radial groove 24, respectively, dry coulombic, or frictional, damping is provided which will further minimize vibration of the inner seal 16 without the use of additional stiffening structures or spring biasing members as found in the prior art. Additionally, inasmuch as ring 20 is transversely split at one cross-section and is therefore a non-hoop member, vibrational response and corresponding aeroelastic instability thereof in ring modes are eliminated.

Another embodiment of the present invention is shown in FIGURE 1 as outer seal 15, which seal is similar to inner seal 16 but of larger diameter and comprising a sealing member having a radial section extending radially inwardly for mating with a complementary radial tongue extending outwardly from the outer portion of turbine nozzle 14. In both embodiments, the sealing member is a composite member as above-described; however, a single member having an axial tongue and a radial groove can also be used. A composite member is preferred because each of the two annular elements 26 and 27 thereof can be manufactured of relatively low cost materials, coated with a hard wear-resistant coating, and rigidly joined together. To manufacture and wear-coat a one piece sealing member having a radial groove therein would require more complex machining and coating processes.

While there has been described herein what is considered to be preferred embodiments of the invention, other modifications will occur to those skilled in the art after having considered the present disclosure. For example, the sealing arrangement of the present invention can be accomplished by various alternative tongue and groove arrangements of the transversely split sealing member 20 in cooperation with co-annular members such as combustor liner 12 and turbine nozzle 14. Specifically, sealing member 20 can comprise axial and radial tongues for mating with complementary annular grooves associated with combustor 12 and turbine nozzle 14. Alternatively, sealing member 20 can comprise axial and radial sections having axial and radial grooves therein, respectively, for mating with complementary axial and radial tongues extending from combustor liner 12 and turbine nozzle 14. Another arrangement can comprise a sealing member 20 having a radial tongue and an axial section having an axial groove therein for mating with a complementary radial groove and axial tongue associated with turbine nozzle 14 and combustor liner 12, respectively. Furthermore, although sealing member 20 is disclosed as preferably having integral annular axial and radial sections, such axial and radial sections can be suitably joined by welding, brazing, or by being bolted together, for example. Accordingly, it is desired to secure by the appended claims, all modifications falling within the true scope and spirit of the invention.

CLAIMS

1. A sealing arrangement for joining a pair of coaxial annular members comprising:

an annular radial flange extending from one of said coaxial annular members;

an annular axial flange extending from the other of said coaxial annular members; and

an annular sealing member coaxially disposed between said pair of annular members and having annular axial and radial sections, said axial section being in slidable sealing engagement with said axial flange and said other coaxial annular member and said radial section being in slidable sealing engagement with said radial flange of said one coaxial annular member, said annular sealing member being transversely split for accommodating relative differential radial thermal expansion and contraction of said annular sealing member and said other coaxial annular member.

2. A sealing arrangement according to claim 1, wherein said annular radial flange defines an annular radial tongue and said radial section of said annular sealing member has an annular radial groove therein for receiving said tongue in slidable sealing engagement, said groove being of sufficient depth to accommodate radial movement of said tongue therein.

3. A sealing arrangement for joining a pair of coaxial annular members comprising:

an annular flange extending from one of the pair of coaxial annular members and defining a radial tongue;

an annular axial flange extending from the other of said pair of coaxial annular members and having an annular axial groove therein; and

an annular sealing member coaxially disposed between said pair of annular members and comprising an annular radial section having an annular radial groove therein receiving said radial tongue in slidable sealing engagement therein, and an integral annular axial section defining an axial tongue being in slidable sealing engagement with at least one sidewall of said axial groove of said other coaxial annular member, said annular sealing member being transversely split for accommodating relative differential radial thermal expansion and contraction of said annular sealing member and said other coaxial annular member.

4. A sealing arrangement according to claim 3, wherein each said tongue is in slidable sealing engagement with both opposite sidewalls of the respective annular groove.

5. A sealing arrangement according to claim 3, wherein said annular sealing member is a composite structure comprising:

a pair of coaxial annular members each having integral axial and radial annular portions, said axial annular portions being rigidly interconnected in parallel alignment for defining said axial section of said annular sealing member; and

said radial annular portions being axially spaced in parallel alignment for defining therebetween said radial groove of said annular sealing member.

6. A sealing arrangement for use between an annular combustor and a coaxial annular turbine nozzle of an axial flow gas turbine engine comprising:

an annular flange coaxially associated with the combustor and having a pair of radially spaced, axially extending parallel annular portions defining an axial groove therebetween;

an annular flange coaxially extending from the turbine nozzle and defining a radial tongue; and

a composite annular sealing member comprising a pair of coaxial annular members each having integral axial and radial annular portions, said axial portions being in parallel alignment and rigidly interconnected and defining an axial tongue being in slidable sealing engagement with both opposite sidewalls of said axial groove of the combustor, and said radial annular portions being axially spaced in parallel alignment for defining a radial groove therebetween in slidable sealing engagement with said radial tongue of the turbine nozzle, said annular sealing member being transversely split for accommodating relative differential radial thermal expansion and contraction of said combustor and said annular sealing member.

7. A sealing arrangement according to claim 6, wherein said radial annular portions of said annular sealing member extend radially outwardly and said radial tongue of said turbine nozzle extends radially inwardly for slidable sealing engagement with said radial groove of said annular sealing member.

8. A sealing arrangement according to claim 6, wherein said radial annular portions of said annular sealing member extend radially inwardly and said radial tongue of said turbine nozzle extends radially outwardly for slidable sealing engagement with said radial groove of said annular sealing member.

9. A sealing arrangement according to claim 1, 3 or 6, wherein said annular sealing member is elastic and transversely split at only a single section.

10. A sealing arrangement according to claim 3 or 6, wherein each said annular groove is of sufficient depth to accommodate longitudinal movement of each respective tongue therein.

11. An annular sealing member for joining a pair of coaxial annular members in slidable sealing engagement comprising an annular radial section having an annular radial groove therein, and an integral annular axial section defining an axial tongue, said annular sealing member being elastic and transversely split at only a single section to allow circumferential expansion and contraction thereof.

12. An annular sealing member according to claim 11, wherein said annular sealing member is a composite structure comprising:

a pair of coaxial annular elements each having integral annular axial and radial portions, said axial portions being rigidly joined in parallel alignment for defining said axial section of said annular sealing member; and

said radial portions being axially spaced in parallel alignment for defining therebetween said radial groove of said annular sealing member.

13. An annular sealing member according to claim 11, wherein said annular radial section extends radially outwardly.

14. An annular sealing member according to claim 11, wherein said annular radial section extends radially inwardly.

15. A sealing member or sealing arrangement substantially as hereinbefore described with reference to and as illustrated in the drawings.

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